Improving Intraocular Lens Calculation in Fuchs Endothelial Dystrophy According To Preoperative Degree of Corneal Edema

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Abstract

Fuchs endothelial dystrophy (FED) is a bilateral, asymmetric, progressive corneal endothelium disorder that causes corneal edema. Resolution of corneal edema is only possible by corneal transplantation.

Cataract surgery is a common surgery that replaces the natural lens of the eye by an artificial intraocular lens (IOL). The IOL-power calculation depends mainly on the anterior corneal keratometry and the axial length. In patients with FED, anterior keratometry may be affected by corneal edema and calculations may be less accurate. Therefore, the aim of this study is to establish the theoretical postoperative refractive error due to corneal edema resolution after Descemet stripping endothelial keratoplasty combined with cataract surgery and IOL implantation. For this, anterior keratometry was measured preoperatively with edematous cornea and postoperatively after corneal edema resolution. Both keratometries were compared and used to calculate the respective theoretical IOL-powers. The difference between target IOLs was used to establish the theoretical refractive error due to corneal edema resolution.

The results showed that corneal edema resolution induces a change in anterior keratometry, which affects IOL-power calculations and causes a hyperopic shift. The patients with moderate-to-severe preoperative corneal edema had higher theoretical refractive error so their target selection should be adjusted for additional $-0.50D$.

Introduction

Fuchs endothelial dystrophy (FED) is a bilateral, asymmetric, progressive corneal endothelium disorder. This autosomal dominant pathology can cause blurry vision secondary to corneal edema, so corneal transplantation is necessary.¹ Intraocular lens (IOL) calculation is a problem when endothelial keratoplasty is combined with cataract surgery in patients with FED. All corneal changes induced by corneal edema can alter IOL calculation and cause higher residual refractive errors.²⁻⁶

Descemet Stripping Automated Endothelial Keratoplasty (DSAEK) has become the most common endothelial keratoplasty for treating endothelial dysfunction in the last decade because it provides, among other advantages, early visual recovery.⁷ Some reports previously advocate that this surgery induces a postoperative mean hyperopic shift of $+1.10D$ (from $+0.70D$ to $+1.50D$),^{7,8} attributed to the concave shape of the donor corneal endothelial lenticule.⁹⁻¹¹ However after Descemet Membrane Endothelial Keratoplasty (DMEK), a minor hyperopic shift has been described of $+0.31D$ (from $+0.03D$ to $+1.20D$).⁷ In DMEK cases, the hyperopic shift cannot be explained by donor lenticule because this is thinner. Hence the concave shape of the donor lenticule is eliminated to prevent postoperative refractive change. It has been suggested that the hyperopic shift could be caused by structural corneal changes associated with corneal edema (flattening of the central posterior keratometry, oblate posterior cornea shape and steepening anterior corneal surface).^{2,3,5,6,12,13}

Surgeons frequently increase the IOL power in endothelial keratoplasty combined with phacoemulsification and IOL implantation (triple-DSAEK or triple-DMEK) to minimize this postoperative mean refractive error (RE). However, a high standard deviation appears in the outcomes that can be explained by differences in the preoperative degree of corneal edema in each patient. The purpose of this study is to quantify the IOL power calculation error (EIOL) due to corneal edema resolution after triple-DSAEK and the RE related to this effect. To the best of our knowledge, our study is the first to estimate the RE according to the degree of preoperative corneal edema. These outcomes will allow more accurate IOL calculations in combined procedures of endothelial keratoplasty.

Results

Thirty-four eyes of 34 patients, of whom 23 (68%) were female and 11 (32%) male, were included. The average patient age was 65.44 ± 9.45 years (range: 49-82 years). All the patients were Caucasian, diagnosed with FED and underwent triple-DSAEK.

Keratometry

Figure 1 show the average preoperative keratometry (K1 or flat corneal keratometry, K2 or steep corneal keratometry and Km or mean corneal keratometry) with edematous cornea (K_{preDSAEK}) compared to the average postoperative keratometry after corneal edema resolution ($K_{\text{postDSAEK}}$).

K_{preDSAEK} was significantly steeper than $K_{\text{postDSAEK}}$. Preoperative keratometry (K1, K2 y Km) were overestimated $+0.43\text{D}$ ($P = 0.048$, 95% CI $0.00\text{-}0.85\text{ D}$), $+0.85\text{D}$ ($P < 0.001$, 95% CI $0.44\text{-}1.27\text{ D}$) and $+0.64\text{D}$ ($P < 0.001$, 95% CI $0.38\text{-}0.90\text{ D}$), respectively.

Intraocular Lens Power Calculations

The power of the IOLs was calculate using true keratometries in a theoretical eye with 24mm axial length.

The theoretical IOL power calculated with K_{preDSAEK} ($\text{IOL}_{\text{preDSAEK}}$) was significantly lower than the theoretical IOL power calculated using $K_{\text{postDSAEK}}$ ($\text{IOL}_{\text{postDSAEK}}$) after corneal edema resolution ($\text{IOL}_{\text{preDSAEK}} = +19.91 \pm 1.58\text{D}$ vs. $\text{IOL}_{\text{postDSAEK}} = +20.60 \pm 1.52\text{D}$; $P < 0.001$, 95% CI $(-0.96)\text{-}(-0.42)\text{ D}$). This difference suggests that preoperative corneal edema underestimates IOL power calculation ($\text{EIOL} = -0.69 \pm 0.78\text{D}$).

Refractive Error Induced by Corneal Edema Resolution

The theoretical RE secondary to power difference between $\text{IOL}_{\text{preDSAEK}}$ and $\text{IOL}_{\text{postDSAEK}}$ was $+0.45 \pm 0.09\text{D}$ (95% CI $0.27\text{-}0.63\text{ D}$). The majority of sample showed hyperopic error (70.6%, $n=24$), while five eyes (14.7%) presented myopic error and five (14.7%) showed no error.

RE significantly correlated with keratometry error (EK1: $r^2 = -0.666$, $P < 0.001$; EK2: $r^2 = -0.527$, $P < 0.001$; EKm: $r^2 = -0.956$, $P < 0.001$), i.e., the higher the overestimation of keratometry measured with corneal edema, the greater the hyperopic shift. However, RE was statistically independent of the preoperative keratometry with corneal edema (RE & K_{preDSAEK} , $P > 0.05$ in all cases)

Results According to the Preoperative Degree of Corneal Edema

The sample was divided into two groups according to the degree of preoperative corneal edema. Seventeen eyes (50%) were classified as "mild edema", and 17 eyes (50%) as "moderate-to-severe" edema. The patients from both groups had similar gender, age and K_{preDSAEK} characteristics ($P > 0.05$ in all the comparisons).

Table 1 shows the keratometry error after corneal edema resolution ($\text{EK} = K_{\text{preDSAEK}} - K_{\text{postDSAEK}}$) according to the preoperative degree of corneal edema.

The patients with preoperative moderate-to-severe corneal edema showed wider overestimation in keratometry after corneal edema reversal. The average Km dropped from $44.09 \pm 1.58\text{D}$ to $43.04 \pm 1.23\text{D}$ after corneal edema resolution ($P < 0.001$, 95% CI $0.65\text{-}1.46\text{ D}$). In contrast, the patients with mild preoperative corneal edema showed narrower Km variations, which diminished from $44.02 \pm 1.34\text{D}$ to $43.80 \pm 1.34\text{D}$ ($P = 0.043$, 95% CI $0.01\text{-}0.44\text{ D}$).

The error observed in the IOL calculation (EIOL) varied depending on the degree of preoperative corneal edema. Thus, IOL power was more underestimated in the patients with moderate-to-severe preoperative corneal edema than in those with mild edema ($-1.09 \pm 0.77\text{D}$ and $-0.29 \pm 0.56\text{D}$, respectively; $P = 0.002$, 95% CI $0.32\text{-}1.26\text{ D}$).

As a result, theoretical RE varied according to the degree of preoperative corneal edema (Figure 2). The average hyperopic RE was $+0.52\text{D}$ greater in the patients with moderate-to-severe preoperative corneal edema than in those with mild preoperative corneal edema ($+0.71 \pm 0.52\text{D}$ and $+0.19 \pm 0.37\text{D}$, respectively; $P = 0.003$, 95% CI $0.21\text{-}0.84$).

Table 2 summarizes the preoperative and postoperative data of all the patients, the degree of corneal edema in each case and the RE induced by corneal edema resolution. The preoperative data include the K-readings (K1, K2 and Km) with corneal edema (K_{preDSAEK}), the theoretical IOL power calculated with corneal edema ($\text{IOL}_{\text{preDSAEK}}$) and the selected target of $\text{IOL}_{\text{preDSAEK}}$. The postoperative data include K-readings after corneal edema resolution ($K_{\text{postDSAEK}}$), the theoretical IOL power calculated after corneal edema resolution ($\text{IOL}_{\text{postDSAEK}}$) and the selected target of $\text{IOL}_{\text{postDSAEK}}$. The selected target on both IOLs was similar ($P = 0.737$).

Discussion

This study observed that triple-DSAEK surgery induced the postoperative flattening of anterior keratometry due to corneal edema resolution after surgery. These changes in postoperative anterior keratometry alter IOL calculations and cause a hyperopic shift.

A hyperopic shift after endothelial keratoplasty is well-known and is commonly explained by changes in the posterior corneal surface. After DSAEK, the concave shape of the donor lenticule induced a negative RE by diminishing the total refractive corneal power.^{8,9,11,15} However, only 2/3 of the RE can be attributed to the shape and size of the donor lenticule.¹¹ After DMEK, the thin donor tissue had no refractive power, so it was unable to justify the hyperopic shift. Even so, it has been demonstrated that postoperative changes in curvature and asphericity of the posterior cornea surface occur after DMEK and reduce the total refractive cornea power.^{2,3,12,16,17} However, the changes found in the posterior corneal surface appeared insufficient to justify the reported total hyperopic shift.

In 2011, Hamm et al. suggested for the first time that FED corneal edema flattened the cornea posterior surface, increased the total refractive corneal power and induced myopia. They also stated that postoperative edema resolution made posterior surface steeper by balancing out the preoperative changes induced by FED corneal edema. Hamm et al. concluded that standard IOL calculations can be applied to cataract surgery performed before or during DMEK.

Recently, some authors have observed that patients with a more marked hyperopic shift after triple-DMEK showed similar preoperative corneal features: corneal posterior surface keratometry was flatter, posterior asphericity was positive and pachymetry was thicker than in normal corneas.^{5,6,17} Furthermore, all authors agree that the changes observed before and after transplant are secondary to changes in the degree of corneal hydration. Thus corneal changes due to edema in FED may determine IOL calculation accuracy in procedures that combine endothelial transplant, phacoemulsification and IOL-implant (triple procedures).^{3,16}

The main IOL calculation devices based on partial coherence interferometry, such as IOL-Master, cannot measure the posterior cornea surface. These devices base their results on third-generation formulas in which the main variables are anterior cornea keratometry and AXL. So if anterior cornea keratometry is not altered by corneal hydration as some authors suggest,^{3,12,16,18} there should be no RE after edema resolution in triple-DMEK. Despite published reports documenting major differences in their surgery results, they all show a clear hyperopic RE trend.⁷ So possibly changes in the anterior corneal surface occur that some IOL calculation devices cannot consider³ and they could play an important role in the RE observed after DSAEK and DMEK, as Clemmensen et al. suggested in 2015.

In our study, the same device was used to measure the preoperative and postoperative keratometries (K_{preDSAEK} and $K_{\text{postDSAEK}}$, respectively). IOL Master 500 showed statistically significant keratometric flattening of approximately 0.60D after edema resolution, which is similar to previous data published by other authors.^{2-4, 19} Therefore, it could be assumed that the corneal edema present in patients with FED overestimates keratometry.

In order to verify the effect of corneal edema on IOL-power selection, we performed IOL calculation twice: once using the initial preoperative keratometry (with corneal edema) and a second with the postoperative keratometry (after edema resolution). We performed these two IOL-power calculations in the same theoretical model eye to eliminate other causes of

error in IOL calculations (such as effective lens position, AXL or formula). Thus, we can verify the direct relation between keratometric change (variable EK) and the error in IOL-power selection (EIOL).

Our results showed that, after edema resolution, IOL-power ($IOL_{\text{postDSAEK}}$) was approximately 1D higher than that calculated with corneal edema (IOL_{preDSAEK}). This difference in IOL calculation occurred because the overestimated preoperative keratometry (K_{preDSAEK}) conditioned insufficient IOL-power (IOL_{preDSAEK}). Finally, the underestimated IOL (IOL_{preDSAEK}) generated a mean theoretical hyperopic shift of + 0.45D after corneal edema resolution (with $K_{\text{postDSAEK}}$). Curiously, the hyperopic error obtained herein was similar to previously published data in a report by the American Academy of Ophthalmology after DMEK (+ 0.31D).⁷ It should be considered that this hyperopic shift is calculated for a theoretical eye with an AXL of 24 mm. Thus, shorter eyes with higher IOL-power will show greater hyperopic errors, while we observed the opposite in longer eyes.

This study is the first one to establish a direct relation between hyperopic shift and the degree of preoperative corneal edema in patients with FED. To date, different authors have theorized that the corneal changes responsible for hyperopic shifts are secondary to variations in the corneal hydration level. However, none has measured or quantified the preoperative corneal edema level. To date, authors have only related changes after endothelial keratoplasty to pachymetric changes^{5,20}, variations in corneal densitometry¹³ or preoperative positive asphericity on the posterior corneal surface⁶. In the present study, we divided our sample in two groups according to the degree of preoperative corneal edema observed by slit lamp (both groups were similar in number, age and preoperative keratometry terms). Data demonstrate that different degrees of preoperative corneal edema induce statistically distinct results.

Specifically, the patients undergoing triple-DSAEK with moderate-to-severe preoperative edema showed more marked keratometry flattening after edema resolution than those with mild preoperative edema. Consequently, the hyperopic shift in the patients with more corneal edema was + 0.52D greater ($+ 0.71 \pm 0.52D$ vs $+ 0.19 \pm 0.37D$, respectively). Therefore, we suggest that the RE related to corneal edema should be considered in IOL-power calculations. Increasing the negative target of IOL according to the preoperative degree of edema could diminish postoperative refractive surprises after triple procedures.

Most surgeons choose a negative IOL target to compensate the hyperopic shift; from - 0.50D to -1.00D in triple-DMEK^{3,5,6,21-23} and from - 0.8D to -1.25D in triple-DSAEK.²⁴⁻²⁶ According to our results, we propose selecting the - 0.19D IOL target in the patients with mild edema and one of -0.71D IOL in those patients with moderate-to-severe edema in triple-DMEK. In triple-DSAEK, an additional myopic target from - 0.62D to -0.97D, secondary to the effect of the donor lenticule, must be added.^{10,11} So in triple-DSAEK, we propose selecting an IOL target from - 0.81D to -1.16D and from - 1.33D to -1.68D in the patients with mild edema and with moderate-to-severe edema, respectively.

When the degree of preoperative corneal edema is not evaluated, choosing a -0.45D myopic target could compensate an average error induced by corneal edema resolution, but with wider variability in the results. This average adjustment in IOL calculation agrees with that suggested by other authors.^{6,20}

Fritz et al. found that those patients who showed preoperative positive asphericity on the posterior corneal surface presented a higher hyperopic shift after DMEK.⁶ These authors suggest that the oblate shape of the posterior corneal surface (positive asphericity) is an indicator of corneal edema worsening in FED progression. So they propose adding - 0.50D of target in those eyes with positive posterior cornea surface asphericity preoperatively. Nevertheless, corneal opacity induced by edema complicates acquiring accurate posterior corneal surface data. This has been demonstrated in corneas with pachymetry over 650 μm measured by Pentacam Scheimpflug imaging.^{6,27} In these cases, slit lamp examination is the quickest, easiest and most reliable method for corneal edema assessments.

As corneal central thickness increases with greater edema, Bae et al. found a higher hyperopic shift after DMEK in thicker corneas.²⁰ These authors propose adding - 0.50D of myopic adjustment of the target in those eyes with a preoperative corneal central thickness of 640 μm or more. With the proposed adjustment, their mean postoperative refractive surprise

dropped from $+1.20 \pm 0.92$ to $+0.70 \pm 0.92$ D. However, corneal central thickness is extremely variable between patients and may not be universally valid for defining the IOL-power target.^{17,28,29} So once again, corneal transparency evaluation by slit lamp could be more reliable for establishing the degree of corneal edema and for setting the IOL target.

Some limitations in the current study should be taken into account. The subjective classification of the preoperative degree of corneal edema may reduce the repeatability of our results. However, we currently have no effective objective systems for grading corneal edema. To reduce the variability of our classification, only two well-differentiated groups were recorded: a mild corneal edema group including clear corneas and moderate-to-severe corneal edema included unclear corneas that do not allow details of anterior chamber to be seen. Besides, corneal irregularities secondary to FED severity could make keratometry acquisition difficult.²⁹ In our study, only repeatable keratometries were recorded. IOL-Master 500 performs keratometries in 2.3 mm of the central cornea.³⁰ Thus, peripheral corneal irregularities secondary to severe edema should not affect (or less affect) the recorded keratometry and our results.

In summary, corneal edema resolution after a triple-DSAEK procedure induces an anterior keratometry flattening of -0.64 D. This corneal flattening induces an error in IOL calculations, which is the cause of an average hyperopic shift of + 0.45D. Moderate-to-severe preoperative corneal edema presented a greater hyperopic shift. Thus, we advocate adding - 0.50D more myopic IOL target in the patients with moderate-to-severe preoperative corneal edema than in those with preoperative mild edema.

Methods

A theoretical study was performed from a retrospective case series according to the tenets of the Declaration of Helsinki. The study was approved by the Ethics Committee of the Hospital General Universitario Reina Sofía, Murcia (Spain). All the participants read and signed an informed consent form for both the surgical procedure and research.

The patients who underwent triple-DSAEK were analyzed retrospectively in this study. If both eyes of a patient underwent the same procedure, only the first eye was analyzed. All surgical procedures were performed by the same experienced surgeon (R.G.O.) from January 2007 to December 2017 at the Hospital General Universitario Reina Sofía, Murcia. The inclusion criteria were FED and cataract diagnosis with best-corrected visual acuity (BCVA) of 0.2 logMAR or worse, performed triple-DSAEK, postoperative follow-up exceeding 6-months, complete postoperative edema resolution and postoperative BCVA of 0.1 logMAR or better. The exclusion criteria were: previous refractive surgery, concurrent keratoconus, surgery complications and follow-up less than 6 months.

Surgical Technique

All surgical procedures were performed by a single surgeon using peribulbar or topical anesthesia. Cataract surgery was carried out with conventional phacoemulsification and IOL implantation in the capsular bag. DSAEK was performed following the cataract procedure. The DSAEK surgery procedure has been previously described by Ortiz-Gomariz et al.¹⁴¹⁴

Recorded Data

Patient demographics, the degree of preoperative corneal edema, preoperative keratometry (K_{preDSAEK}) and postoperative keratometry ($K_{\text{postDSAEK}}$) were recorded. The degree of preoperative corneal edema was subjectively evaluated by a corneal surgeon based on slit lamp findings. Mild edema was defined as minimal microcystic corneal edema in patients in early FED stages. In this stage, corneal clearance must allow the perfect visualization of iris and lens details. Moderate-to-severe edema was defined as evident stromal corneal edema in the patients with advanced FED. This advanced degree of corneal edema does not allow the perfect visualization of iris or lens details. Postoperative keratometry was recorded at least 6 months after surgery after complete edema resolution (the cornea should be clear, and the BCVA should be 0.1 LogMAR or better).

Keratometry

The preoperative and postoperative keratometry (K) data were obtained by IOL-Master 500 (Carl Zeiss, Germany). Each measure was repeated 3 times and the average was recorded. Each K-reading included K1 (flat corneal keratometry), K2 (steep corneal keratometry) and Km (mean corneal keratometry).

Preoperative and postoperative K-readings were compared. Keratometry error (EK) was calculated by the difference between preoperative keratometry and postoperative keratometry ($EK = K_{\text{preDSAEK}} - K_{\text{postDSAEK}}$). Positive values suggest an overestimation of the preoperative K-reading due to corneal edema, while negative values imply underestimated preoperative K-readings.

Intraocular Lens Power Calculation

Real K-readings were used for calculated two intraocular lens (IOL) in a theoretical eye model with an axial length (AXL) of 24 mm. Thus we obtained IOL_{preDSAEK} using preoperative keratometry (K_{preDSAEK}), and we also calculated $IOL_{\text{postDSAEK}}$ with postoperative keratometry ($K_{\text{postDSAEK}}$) after corneal edema resolution. IOL-Master 500 (Carl Zeiss, Germany), SRK/T formula, IOL-constant 119.3 and target spherical equivalent closet to -0.25D were used in all the calculations to avoid other error factors.

Both IOLs power were compared. The EIOL was obtained by the power difference between IOL_{preDSAEK} power and $IOL_{\text{postDSAEK}}$ power ($EIOL = IOL_{\text{preDSAEK}} - IOL_{\text{postDSAEK}}$). Positive values suggest overestimated IOL powers due to preoperative corneal edema, while negative values imply underestimated IOL power.

Refractive Error

Theoretical RE was defined as the expected postoperative refraction with IOL_{preDSAEK} after postoperative corneal edema resolution with $K_{\text{postDSAEK}}$.

RE was calculated by the arithmetic difference between the predicted spherical equivalent (PSE) with power- IOL_{preDSAEK} and power- $IOL_{\text{postDSAEK}}$ ($RE = PSE_{IOL_{\text{preDSAEK}}} - PSE_{IOL_{\text{postDSAEK}}}$) using the theoretical eye model with an AXL of 24 mm and postoperative K-readings. Positive RE values indicate a hyperopic shift after corneal edema resolution, while negative values denote a myopic shift.

Statistical analysis

Data distribution normality was verified by the Kolmogorov-Smirnov test. The data before and after surgery were compared by a paired *t* test. RE was calculated and correlated with the other parameters by a Rho-Spearman correlation test. Finally, the sample was divided into two groups according to the degree of preoperative corneal edema. The statistical differences between the two groups, defined by the preoperative degree of corneal edema ("mild edema" and "moderate-to-severe edema"), were determined by an unpaired *t* test (parametric variables: age, keratometry, IOL power) and a U-Mann-Whitney test (nonparametric variables: RE). A *P*-value ≤ 0.05 was considered statistically significant.

Declarations

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AUTHOR CONTRIBUTIONS:

B.G-M. and R.G-O. designed the study. R.G-O performed all surgeries. Data collection and statistical analyses were done by B.G-M.. Paper manuscript was written by B.G-M., A.O-G and A.M.G-R.. J.J.G-M. and R.G-O made critical revisions. All authors

reviewed, revised and approved the final manuscript.

COMPETING INTERESTS:

The authors declare no competing interests.

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Tables

Table 1: Keratometry error secondary to preoperative corneal edema ($EK = K_{\text{preDSAEK}} - K_{\text{postDSAEK}}$) according to edema groups

	Mild Edema			Moderate-to-Severe Edema			Difference between edema groups			<i>P</i>
	Mean±SD	95% CI		Mean±SD	95% CI		Mean	95% CI		
		Lower	Up		Lower	Up		Lower	Up	
E K1 (D)	0.21 ± 0.87	-0.24	0.65	0.65 ± 1.42	-0.12	1.41	0.44	-0.41	1.29	0.292
E K2 (D)	0.25 ± 0.65	-0.09	0.58	1.46 ± 1.30*	0.79	2.13	1.21	0.50	1.93	0.002**
E Km (D)	0.23 ± 0.42*	0.01	0.44	1.06 ± 0.78*	0.65	1.46	0.83	0.38	1.28	0.001**

E = Error induced by difference between preoperative data with corneal edema and postoperative data without corneal edema ($E = K_{\text{preDSAEK}} - K_{\text{postDSAEK}}$); D=Diopters; K1=Flat keratometry; K2=Steep keratometry; Km=Mean keratometry.

* Statistically significant differences between K_{preDSAEK} and $K_{\text{postDSAEK}}$ by T-Student-Paired-Sampled test ($P \leq 0.05$).

** Statistically significant differences between Mild Edema group and Moderate-to-Severe Edema group by T-Student-Unpaired-Sampled test ($P \leq 0.05$).

Table 2: All patient data are shown: Degree of corneal edema; preoperative data that include k-readings with corneal edema ($K_{preDSAEK}$); IOL-power calculated with $K_{preDSAEK}$ ($IOL_{preDSAEK}$) and predicted spherical equivalent obtained with $IOL_{preDSAEK}$; postoperative data that include postoperative K-readings after corneal edema resolution ($K_{postDSAEK}$), IOL-power calculated with $K_{postDSAEK}$ ($IOL_{postDSAEK}$) and predicted spherical equivalent obtained with $IOL_{postDSAEK}$; and theoretical refractive error induced by $IOL_{preDSAEK}$ secondary to keratometric change after postoperative corneal edema resolution.

Patient	Degree of Edema	Preoperative Data (D)					Postoperative Data (D)					Error (D)
		K1	K2	Km	IOL	PSE	K1	K2	Km	IOL	PSE	RE
1	Mild	43.77	46.36	45.06	19.00	-0.37	41.87	47.34	44.61	19.50	-0.27	+0.32
2	Mild	43.16	43.6	43.38	20.50	-0.18	42.99	43.32	43.16	21.00	-0.35	+0.33
3	Mild	41.16	43.16	42.16	22.00	-0.29	41.11	42.4	41.75	22.50	-0.34	+0.34
4	Mild	41.06	42.45	41.76	22.50	-0.34	42.08	42.67	42.38	22.00	-0.46	-0.35
5	Mild	43.27	47.47	45.37	18.50	-0.22	45.00	45.73	45.36	18.50	-0.28	+0.00
6	Mild	40.91	41.56	41.23	23.00	-0.32	39.99	40.91	40.45	24.00	-0.44	+0.71
7	Mild	43.66	45.24	44.45	19.50	-0.27	41.98	45.36	43.67	20.50	-0.34	+0.66
8	Mild	42.83	44.12	43.47	20.50	-0.24	42.72	43.89	43.31	20.50	-0.12	+0.00
9	Mild	45.18	47.07	46.13	17.50	-0.17	45.00	45.79	45.39	18.50	-0.3	+0.62
10	Mild	44.88	45.36	45.12	18.50	-0.12	44.53	44.88	44.7	19.00	-0.14	+0.32
11	Mild	43.60	44.35	43.98	20.00	-0.27	43.83	44.76	44.3	19.50	-0.17	-0.33
12	Mild	44.94	46.23	45.58	18.00	-0.12	44.47	45.92	45.2	18.50	-0.16	+0.32
13	Mild	44.12	44.47	44.30	19.50	-0.17	43.66	44.47	44.06	20.00	-0.33	+0.32
14	Mild	42.83	45.18	44.00	20.00	-0.27	43.27	45.24	44.26	19.50	-0.13	-0.33
15	Mild	43.49	44.47	43.98	20.00	-0.27	43.32	44.53	43.92	20.00	-0.23	+0.00
16	Mild	43.77	45.36	44.56	19.50	-0.36	44.06	45.67	44.87	19.00	-0.24	-0.32
17	Mild	43.72	44.06	43.89	20.00	-0.21	42.94	43.44	43.19	21.00	-0.37	+0.66
18	Moderate-Severe	43.00	47.30	45.15	19.00	-0.37	42.88	44.47	43.67	20.50	-0.38	+0.98
19	Moderate-Severe	43.44	44.18	43.81	20.00	-0.15	42.35	42.72	42.53	21.50	-0.23	+1.00
20	Moderate-Severe	44.58	45.73	45.16	18.50	-0.14	43.60	45.30	44.45	19.50	-0.27	+0.63
21	Moderate-Severe	43.16	49.20	46.18	18.00	-0.39	43.38	44.53	43.95	20.00	-0.25	+1.28
22	Moderate-Severe	39.11	45.36	42.23	22.00	-0.19	41.51	42.88	42.20	22.00	-0.32	+0.00
23	Moderate-Severe	43.83	46.62	45.22	18.50	-0.16	44.18	45.18	44.68	19.00	-0.12	+0.32
24	Moderate-Severe	42.67	44.00	43.34	20.50	-0.14	41.87	42.61	42.24	22.00	-0.36	+1.01

25	Moderate-Severe	45.42	45.98	45.70	18.00	-0.20	44.00	44.82	44.41	19.50	-0.25	+0.95
26	Moderate-Severe	41.46	43.32	42.39	21.50	-0.12	41.72	42.83	42.27	22.00	-0.38	+0.34
27	Moderate-Severe	42.51	44.35	43.43	20.50	-0.20	40.81	42.19	41.50	22.50	-0.15	+1.36
28	Moderate-Severe	42.40	43.16	42.78	21.50	-0.41	39.52	41.51	40.52	23.50	-0.12	+1.39
29	Moderate-Severe	40.27	44.35	42.31	22.00	-0.34	42.56	42.72	42.64	21.50	-0.31	-0.35
30	Moderate-Severe	42.51	43.89	43.20	21.00	-0.37	41.77	43.10	42.44	21.50	-0.16	+0.34
31	Moderate-Severe	41.00	42.50	41.75	22.50	-0.34	39.75	43.64	41.69	22.50	-0.25	+0.00
32	Moderate-Severe	44.47	47.60	46.03	18.00	-0.39	43.55	45.18	44.36	19.50	-0.21	+0.95
33	Moderate-Severe	46.36	47.14	46.75	17.00	-0.29	43.21	47.40	45.31	18.50	-0.18	+0.93
34	Moderate-Severe	43.30	44.90	44.15	20.00	-0.35	41.87	43.66	42.77	21.50	-0.39	+1.00

D=Diopters; RE= Refractive Error induced in the IOL calculation secondary to keratometric change after corneal edema resolution. K1=Flat keratometry; K2=Steep keratometry; Km=Mean keratometry; IOL=Intraocular Lens; PSE= Predicted Spherical Equivalent

Figures

Figure 1:

Figure 1

Preoperative K-readings with corneal edema (KpreDSAEK) versus postoperative K- readings (KpostDSAEK) without corneal edema. * Statistically significant data ($P \leq 0.001$) by a T-Student-Paired-Sampled test

Figure 2:

Figure 2

Refractive error (RE) induced by corneal edema resolution according to the degree of preoperative corneal edema. The patients with moderate-to-severe edema (black) show a higher hyperopic error than those with mild edema (white).